sumed in making the bronze, which consists of 250 kilog. of gold, 8413·5 of tin, 977 of mercury, and 493 of copper. The present image only dates from 1801.

We have received a German pamphlet by Herr Max Buch, on "Finland and its Nationality Question," being a reprint of papers which have appeared in recent issues of the *Ausland*. In the limited space of seventy-four pages the author gives a short but correct description of Finland, of the prehistoric Finns, according to Ahlquist's researches, of the history of the country, and of the present state of the "national question." He summarises the excellent researches by Retzius on the race-characters of the Finns—as far as can be done in a few pages—and dwells upon the recent efforts of Finnish writers towards the development of the Finnish language and literature as a reaction against the former supremacy of the Swedish language and influence. We notice the interesting fact that although only 7·5 per cent. of the Finns can now read and write, and 70 per cent. read, primary instruction has taken during the last few years a great extension. The number of State schools being too limited, they are supplemented by private instruction. Thus, of the 342,836 children from seven to sixteen years old of the Lutheran Finnish population, only 6983 had not received primary instruction in 1877 (1801 of them on account of disease). But only 26,900 went to the State schools, whilst 116,201 children received primary instruction in private ambulatory schools, and 177,925 at home.

The last number of the *Izvestia* of the Russian Geographical Society contains several interesting papers. M. Veselago gives a sketch of the life and work of the late Count Lütke. Prof. Fr. Schmidt discusses again the claim of Wrangel to the discovery of the land situated north of the Cape Yakan. He tries to prove, against Nordenskjöld, that Wrangel was right in denying the existence of a land which Andréeff said he saw from the fifth island of the Medvyejiy Archipelago; but he did not deny the existence of a land situated north of Cape Yakan. Prof. Schmidt admits, however, that even with regard to this land, Wrangel wrote "in different parts of his report with a varying degree of certainty as to the probability of its existence." M. Karzin, an official of the Verkhoyansk district, having been struck with the terrible fate of De Long, publishes a most valuable list of all settlements and places where human beings can be met with at different seasons on the coast of North-Eastern Siberia. M. Andréeff publishes a brief account of his hydrographical researches in the White Sea and on the Murman coast during the last three years. The flora of the coast becomes very poor north of Archangel. At the Svyatoy Noss lighthouse it consists only of lichens, mosses, and creeping brushes of *Betula nana*. It improves, however, west of Kildin and especially west of the Ribachiy peninsula, offering excellent forests and meadows at the new colony at Pechenga. The yearly average temperature, which is but $-$ 0°·6 Celsius at Archangel, and $-$ 2°·4 at the Svyatoy Noss lighthouse, reaches $-$ 1°·1 at Kola, and + 1°·4 at Vardö. This increase of temperature is due, as is known, to the warm current which flows along the coast. Thus, at Svyatoy Noss, during the hottest days, the temperature of water does not exceed 6°·9; and during the autumn it reaches but 1°·9. To the west of 30° 6′ it suddenly becomes double that. In the spring the warm streamlets reach 4°·3, whilst the cold ones, flowing close by, reach but 1°·9; and during the summer the warm streamlets reach 12°·5, whilst the cold ones, close by, reach 6°·9 to 7°·5. It appears thus that one isolated measurement of temperature of water is of little value, the warm current being not so compact along the Murman coast as elsewhere. Under 33° 6′ E. long. it leaves the coast and flows towards the north-north-east. The positions taken by the warm current at the Murman coast vary with the seasons, and depend upon the prevailing winds. From April to August it touches the coast, but later on it is driven north by the southern winds; in October it already flows off Vardö. Its position varies also for different years, depending upon the prevailing winds. The richness of the fishing depends entirely upon the position taken by the warm current. In 1881, the Norwegians, owing to the current flowing in their waters, had the richest prey, whilst in 1882, the richest prey for a twenty years' series was given by the warm current to the Russian fishers. The same number of the *Izvestia* contains the first sheets of M. Polakoff's reports on his researches in Sakhalin, and M. Mezhoff's bibliographical index of the Russian geographical literature for the year 1880.

M. Thouar, the French traveller, has written a letter from Chili, in which he says that several members of the exploring party under Dr. Jules Crevaux, who was massacred with most of his followers in the early part of last year by Indians while making explorations along the Bolivian part of the Pilcomayo, are believed to be still alive, but prisoners in the hands of the Indians.

THE CAUSE OF EVIDENT MAGNETISM IN IRON, STEEL, AND OTHER MAGNETIC METALS[1]

Neutrality

The apparatus needed for researches upon evident external polarity requires no very great skill or thought, but simply an apparatus to measure correctly the force of the evident repulsion or attraction; in the case of neutrality, however, the external polarity disappears, and we consequently require special apparatus, together with the utmost care and reflection in its use.

From numerous researches previously made by means of the induction balance, the results of which I have already published, I felt convinced that in investigating the cause of magnetism and neutrality I should have in it the aid of the most powerful instrument of research ever brought to bear upon the molecular construction of iron, as indeed of all metals. It neglects all forces which do not produce a change in the molecular structure, and enables us to penetrate at once to the interior of a magnet or piece of iron, observing only its peculiar structure and the change which takes place during magnetisation or apparent neutrality.

The induction balance is affected by three distinct arrangements of molecular structure in iron and steel, by means of which we have apparent external neutrality.

Fig. 1 shows several polar directions of the molecules as indicated by the arrows. Poisson assumed, as a necessity of his theory, that a molecule is spherical, but Dr. Joule's experimental proof of the elongation of iron by 1/720,000th of its length when magnetised, proves at least that its form is not spherical; and as I am unable at present to demonstrate my own views as to its exact form, I have simply indicated its polar direction by arrows—the dotted oval lines merely indicating its limits of free elastic rotation.

In Fig. 1, at A, we have neutrality by the mutual attraction of each pair of molecules, being the shortest path in which they could satisfy their mutual attractions. At B we have the case of superposed magnetism of equal external value, rendering the wire or rod apparently neutral, although a lower series of molecules are rotated in the opposite direction to the upper series, giving to the rod opposite and equal polarities. At C we have the molecules arranged in a circular chain around the axis of a wire or rod through which an electric current has passed. At D we have the evident polarity induced by the earth's directive influence when a soft iron rod is held in the magnetic meridian. At E we have a longitudinal neutrality produced in the same rod when placed magnetic west, the polarity in the latter case being transversal.

In all these cases we have a perfectly symmetrical arrangement, and I have not yet found a single case in well-annealed soft iron in which I could detect a heterogeneous arrangement, as supposed by Ampère, De la Rive, Weber, Wiedermann, and Maxwell.

We can only study neutrality with perfectly soft Swedish iron. Hard iron and steel retain previous magnetisations, and an apparent external neutrality would in most cases be the superposition of one magnetism upon another of equal external force in the opposite direction, as shown in B, Fig. 1. Perfectly soft iron we can easily free, by vibrations, from the slightest trace of previous magnetism, and study the neutrality produced under varying conditions.

If we take a flat bar of soft iron, of 30 or more centimetres in length, and hold it vertically (giving while thus held a few torsions, vibrations, or, better still, a few slight blows with a wooden mallet, in order to allow its molecules to rotate with perfect freedom), we find its lower end to be of strong north polarity, and its upper end south. On reversing the rod and repeating the vibrations, we find that its lower end has pre-

[1] Paper read before the Society of Telegraph Engineers and of Electricians, on May 24, 1883, by Prof. D. E. Hughes, F.R.S., Vice-President Continued from p. 162.

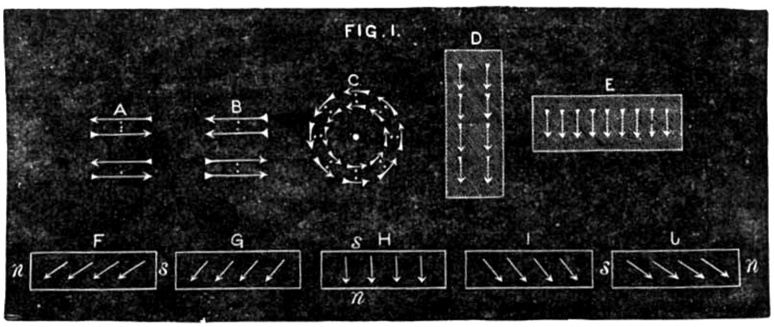
cisely a similar north polarity. Thus the iron is homogeneous, and its polarity symmetrical. If we now magnetise this rod to produce a strong south pole at its lower portion, we can gradually reverse this polarity, by the influence of earth's magnetism, by slightly tapping the upper extremity with a small wooden mallet. If we observe this rod by means of a direction needle at all parts, and successively during its gradual passage from one polarity to the other, there will be no sudden break into a haphazard arrangement, but a gradual and perfectly symmetrical rotation from one direction to that of the opposite polarity.

If this rod is placed east and west, having first, say, a north polarity to the right, we can gradually discharge or rotate the molecules to zero, and as gradually reverse the polarity by simply inclining the rod so as to be slightly influenced by earth's magnetism; and at no portion of this passage from one polarity to neutrality, and to that of the opposite name, will there be found a break of continuity of rotation or haphazard arrangement. If we rotate this rod slowly, horizontally or vertically, taking observations at each few degrees of rotation of an entire revolution, we find still the same gradual symmetrical change of polarity, and that its symmetry is as complete at neutrality as in evident polarity.

In all these cases there is no complete neutrality, the longitudinal polarity simply becoming transversal when the rod is east and west. F, G, H, I, J, Fig. 1, show this gradual change, H being neutral longitudinally, but polarised transversely. If, in place of the rod, we take a small square soft iron plate and allow its molecules freedom under the sole influence of the earth's magnetism, then we invariably find the polarity in the direction of the magnetic dip, no matter in what position it be held, and a sphere of soft iron could only be polarised in a similar direction. Thus we can never obtain complete external neutrality whilst the molecules have freedom and do not form an internal closed circle of mutual attractions; and whatever theory we may adopt as to the cause of polarity in the molecule, such as Coulomb's, Poisson's, Ampère's, or Weber's, there can exist no haphazard arrangement in perfectly soft iron, as long as it is free from all external causes except the influence of the earth; consequently these theories are wrong in one of their most essential parts.

We can, however, produce a closed circle of mutual attraction in iron and steel, producing complete neutrality as long as the structure is not destroyed by some stronger external directing influence.

Oersted discovered that an external magnetic needle places itself perpendicular to an electric current; and we should expect that, if the molecules of an iron wire possessed inherent polarity and could rotate, a similar effect would take place in the interior of the wire to that observed by Oersted. Wiedermann first remarked this effect, and it has been known as circular magnetism. This circle, however, consists really in each molecule having placed itself perpendicular to the current, simply obeying Oersted's law, and thus forming a complete circle in which the mutual attractions of the molecules forming that circle are satisfied, as shown at C, Fig. 1. This wire becomes completely neutral, any previous symmetrical arrangement of polarity rotating to form its complete circle of attractions; and we can thus form in hard iron and steel a neutrality extremely difficult to break up or destroy. We have evident proof that this neutrality consists of a closed chain, or circle, as by torsion we can partially deflect them on either side; thus, from a perfect externally neutral wire, producing either polarity, by simple mechanical angular displacement of the molecules, as by right- or left-handed torsion.



If we magnetise a wire placed east and west, it will retain this polarity until freed by vibrations, as already remarked. If we pass an electric current through this magnetised wire, we can notice the gradual rotation of the molecules, and the formation of the circular neutrality. If we commence with a weak current, gradually increasing its strength, we can rotate them as slowly as may be desired. There is no sudden break or haphazard moment of neutrality: the movements to perfect zero are accomplished with perfect symmetry throughout.

We can produce a more perfect and shorter circle of attractions by the superposition of magnetism, as at B, Fig. 1. If we magnetise a piece of steel or iron in a given direction with a strong magnetic directing power, the magnetism penetrates to a certain depth. If we slightly diminish the magnetising power, and magnetise the rod in a contrary direction, we may reduce it to zero by the superposition of an exterior magnetism upon one of a contrary name existing at a greater depth; and if we continue this operation, gradually diminishing the force at each reversal, we can easily superpose ten or more distinct symmetrical arrangements, and as their mutual attractions are satisfied in a shorter circle than that produced by electricity, it is extremely difficult to destroy this formation when once produced.

The induction balance affords also some reasons for believing that the molecules not only form a closed circle of attractions, as at B, but that they can mutually react upon each other, so as to close a circle of attractions as a double molecule, as shown at A. The experimental evidence, however, is not sufficient to dwell on this point, as the neutrality obtained by superposition is somewhat similar in its external effects.

We can produce a perfectly symmetrical closed circle of attractions of the nature of the neutrality of C, Fig. 1, by forming a steel wire into a closed circle, 10 centimetres in diameter, if this wire is well joined at its extremities by twisting and soldering. We can then magnetise this ring by slowly revolving it at the extremity of one pole of a strong permanent magnet; and, to avoid consequent poles at the part last touching the magnet, we should have a graduating wedge of wood, so that whilst revolving, it may be gradually removed to greater distance. This wire will then contain no consequent points or external magnetism: it will be found perfectly neutral in all parts of its closed circle. Its neutrality is similar to C, Fig. 1; for if we cut this wire at any point we find extremely strong magnetic polarity, being magnetised by this method to saturation, and having retained (which it will indefinitely) its circle of attractions complete.

I have already shown that soft iron, when its molecules are allowed perfect freedom by vibration, invariably takes the polarity of the external directing influence, such as that of the earth, and it does so even with greater freedom under the influence of heat. Manufacturers of electromagnets for telegraphic instruments are very careful to choose the softest iron and thoroughly anneal it; but very few recognise the importance as regards the position of the iron whilst annealing it under the earth's directing influence. The fact, however, has long since been observed.

Dr. Hooke (1684) remarked that steel or iron was magnetised when heated to redness and placed in the magnetic meridian. I have slightly varied this experiment by heating to redness three similar steel bars, two of which had been previously magnetised

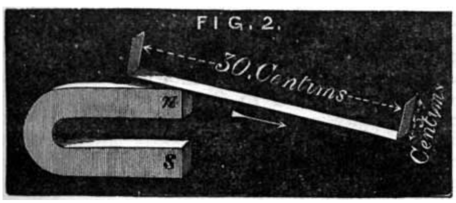
to saturation, and placed separately with contrary polarity as regards each other, the third being neutral. Upon cooling, these three bars were found to have identical and similar polarity. Thus the molecules of this most rigid material, cast steel, had become free at red heat, and rotated under the earth's magnetic influence, giving exactly the same force on each; consequently the previous magnetisation of two of these bars had neither augmented nor weakened the inherent polarity of their molecules. Soft iron gave under these conditions by far the greatest force, its inherent polarity being greater than that of steel.

I have made numerous other experiments bearing upon the question of neutrality, but they all confirm those I have cited, which I consider afford ample evidence of the symmetrical arrangement of neutrality.

Superposed Magnetism.—Knowing that by torsion we can rotate or diminish magnetism, I was anxious to obtain by its means a complete rotation from north polarity to neutrality, and from neutrality to south polarity, or to completely reverse magnetic polarity by a slight right or left torsion.

I have succeeded in doing this and in obtaining strong reversal of polarities by superposing one polarity given whilst the rod is under a right elastic torsion, with another of the opposite polarity given under a left elastic torsion, the neutral point then being reached when the rod is free from torsion. The rod should be very strongly magnetised under its first or right-hand torsion, so that its interior molecules are rotated, or, in other words, magnetised to saturation; the second magnetisation in the contrary sense and torsion should be feebler, so as only to magnetise the surface, or not more than one-half its depth: these can be easily adjusted to each other so as to form a complete polar balance of force, producing, when the rod is free from torsion, the neutrality as shown at B, Fig. 1.

The apparatus needed is simply a good compound horseshoe permanent magnet, 15 centimetres long, having six or more plates, giving it a total thickness of at least 3 centimetres. We need a sufficiently powerful magnet, as I find that I obtain a more equal distribution of magnetism upon a rod or strip of iron by drawing it lengthwise over a single pole in a direction from



that pole, as shown in Fig. 2; we can then obtain saturation by repeated drawings, keeping the same molecular symmetry in each experiment.

In order to apply a slight elastic torsion when magnetising rods or wires, I have found it convenient to attach two brass clamp keys to the extremities of the rods, or simply turn the ends at right angles, as shown in the following diagram, by which means we can apply an elastic twist or torsion whilst drawing the rod over the pole of the permanent magnet. We can thus superpose several and opposite symmetrical structures, producing a polar north or south as desired, greatly in excess of that possible under a single or even double magnetisation, and by carefully adjusting the proportion of opposing magnetisms so that both polarities have the same external force, the rod will be at perfect external neutrality when free from torsion.

If we now hold one end of this rod at a few centimetres distance from a magnetic directive needle, we find it perfectly neutral when free of torsion, but the slightest torsion right or left at once produces violent repulsion or attraction, according to the direction of the torsion given to the rod, the iron rod or strips of hoop-iron which I use for this experiment being able, when at the distance of 5 centimetres from the needle, to turn it instantly 90° on either side of its zero.

The external neutrality that we can now produce at will is absolute, as it crosses the line of two contrary polarities, being similar to the zero of my electric sonometer, whose zero is obtained by the crossing of two opposing electric forces.

This rod of iron retains its peculiar powers of reversal in a remarkable degree, a condition quite different to that of ordinary magnetisation, for the same rod, when magnetised to saturation under a single ordinary magnetism, loses its evident magnetism by a few elastic torsions, as I have already shown; but when it is magnetised under the double torsion with its superposed magnetism, it is but slightly reduced by variations or numerous torsions, and I have found it impossible to render this rod again free from its double polar effects, except by strongly remagnetising it to saturation with a single polarity. The superposed magnetism then becomes a single directive force, and we can then by a few vibrations or torsions reduce the rod to its ordinary condition.

The effects of superposed magnetism and its double polarity I have produced in a variety of ways, such as by the electro-magnetic influence of coils, or in very soft iron simply by the directive influence of the earth's magnetism, reversing the rod and torsions when held in the magnetic meridian, these rods when placed magnetic west showing distinctly the double polar effects.

It is remarkable, also, that we are enabled to superpose and obtain the maximum effects on thin strips of iron from a quarter to half a millimetre in thickness, whilst in thicker rods we have far less effect, being masked by the comparatively neutral state of the interior, the exterior molecules then reacting upon those of the interior, allowing them to complete in the interior their circle of attractions.

I was anxious to obtain wires which would preserve this structure against the destructive influence of torsion and vibrations, so that I could constantly employ the same wires without the comparatively long and tedious process of preparation. Soft iron soon loses the structure or becomes enfeebled under the constant to and fro torsions requisite where we desire a constant change of polarity, as described later in the magnetic bells. Hard steel preserves its structure, but its molecular rigidity is so great that we obtain but mere traces of any change of polarity by torsion. I have found, however, that fine cast drill steel, untempered, of the kind employed by watchmakers, is most suitable: these are generally sold in straight lengths of 30 centimetres. Wires 1 millimetre in diameter should be used, and when it is desired to increase the force, several of these wires, say nine or ten, should be formed into a single rod or bunch.

The wire as sold is too rigid to give its maximum of molecular rotation effect. We must therefore give it two entire turns or twists to the right, and strongly magnetise it on the north pole of the magnet whilst under torsion. We must again repeat this operation in the contrary direction, after restoring the wire to its previous position, giving now two entire turns to the left and magnetising it on the south pole. On restoring the wire to its original place it will be extremely flexible, and we may now superpose several contrary polarities under contrary torsions, as already described.

The power of these wires, if properly prepared, is most remarkable, being able to reverse their polarity under torsion, as if they were completely saturated; and they preserve this power indefinitely if not touched by a magnet. It would be extremely difficult to explain the action of the rotative effects obtained in these wires under any other theory than that which I have advanced; and the absolute external neutrality that we obtain in them when the polarities are changing, we know from their structure to be perfectly symmetrical.

I was anxious to show, upon the reading of this paper, some mechanical movement produced by molecular rotation, consequently I have arranged two bells that are struck alternately by a polarised armature put in motion by the double polarised rod I have already described, but whose position, at 3 centimetres distant from the axis of the armature, remains invariably the same. The magnetic armature consists of a horizontal light steel bar suspended by its central axle; the bells are thin wine glasses, giving a clear musical tone loud enough, by the force with which they are struck, to be clearly heard at some distance. The armature does not strike these alternately by a pendulous movement, as we may easily strike only one continuously, the friction and inertia of the armature causing its movements to be perfectly dead-beat when not driven by some external force, and it is kept in its zero position by a strong directive magnet placed beneath its axle.

The mechanical power obtained is extremely evident, and is sufficient to put the sluggish armature in rapid motion, striking the bells six times per second, and with a power sufficient to produce tones loud enough to be clearly heard in all parts of the hall of the Society. As this is the first direct transformation of molecular motion into mechanical movement, I am happy to show it on this occasion.

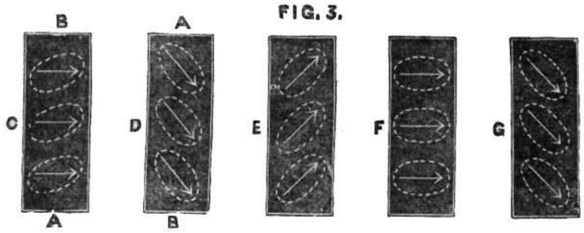
There is nothing remarkable in the bells themselves, as they evidently could be rung if the armature was surrounded by a coil, and worked by an electric current from a few cells. The marvel, however, is in the small steel superposed magnetic wire producing by slight elastic torsions from a single wire, 1 millimetre in diameter, sufficient force from mere molecular rotation to entirely replace the coil and electric current.

Elastic Nature of the Ether surrounding the Magnetic Molecules.—During these researches I have remarked a peculiar property of magnetism, viz., that not only can the molecules be rotated through any degree of arc to its maximum, or saturation, but that, whilst it requires a comparatively strong force to overcome its rigidity or resistance to rotation, it has a small field of its own through which it can move with excessive freedom, trembling, vibrating, or rotating through a small degree with infinitely less force than would be required to rotate it permanently on either side. This property is so marked and general that we can observe it without any special iron or apparatus.

Let us take a flat rod of ordinary hoop-iron, 30 or more centimetres in length. If, whilst holding this vertically, we give freedom to its molecules by torsions, vibrations, or, better still, by a few blows with a wooden mallet upon its upper extremity, we find, as is well known, that its lower portion is strongly north, and its upper south. If we reverse this rod, we now find it neutral at both extremities. We might here suppose that the earth's directing force had rotated the molecules to zero or transversely, which in reality it has done, but only to the limit of their comparatively free motion; for if we reverse the rod to its original position, its previous strong polarity reappears at both extremities, thus the central point of its free motion is inclined to the rod, giving by its free motion great symmetrical inclination and polarity in one direction, but when reversed the inclination is reduced to zero.

In Fig. 3 D shows the bar of iron when strongly polarised by earth's magnetic influence, under vibrations, with a sufficient

FIG. 3.



force to have rotated its elastic centre of action. C shows the same bar with its molecules at zero, or transversal, the directing force of earth being insufficient without the aid of mechanical vibration to allow them to change. The dotted lines of D suppose the molecule to be in the centre of its free motion, whilst at C the molecules have rotated to zero, as they are prevented from further rotation by being at the extreme end of its free motion

If, now, we hold the rod vertically, as at C, giving neutrality, and give a few slight blows with a wooden mallet to its upper extremity, we can give just the amount of freedom required for it to produce evident polarity, and we then have equal polarity no matter which end of the bar is below, the centre of its free rotation here being perfect, and the rod perfectly neutral longitudinally when held east and west. If, on the other hand, we have given too much freedom by repeated blows of the mallet, its centre of free motion becomes inclined with the molecules, and we arrive at its first condition, except that it is now neutral at D and polarised at C. From this it will be seen that we can adjust this centre of action, by vibrations or blows, to any point within the external directing influence.

We can perceive this effect of free rotation in a limited space in all classes of iron and steel, being far greater in soft Swedish iron than in hard iron or steel. A similar phenomenon takes place if we magnetise a rod held vertically in the direction of earth's magnetism. It then gives greater polarity than if magnetised east or west, and if magnetised in a contrary sense to earth's magnetism, it is very feebly magnetised, or, if the rod is perfectly soft, it becomes neutral after strong magnetisation. This property of comparative freedom, and the rotation of its centre of action, can be demonstrated in a variety of ways. One remarkable example of it consists in the telephone. All those who are thoroughly acquainted with electro-magnetism and know that it requires measurable time to charge an electro-magnet to saturation (about one-fifteenth of a second for those employed in telegraphy), were surprised that the telephone could follow the slightest change of timbre, requiring almost innumerable changes of force per second. I believe the free rotation I have spoken of through a limited range explains its remarkable sensitiveness and rapidity of action, and, according to this view, it would also explain why loud sounding telephones can never repeat all the delicacy of timbre that is easily done with those only requiring a force comprised in the critical limits of its free rotation. This property, I have found, has a distinct critical value for each class of iron. and I propose soon to publish researches upon the molecular construction of steel and iron, in which I have made use of this very property as a guide to the quality of the iron itself.

The elastic rotation (in a limited space) of a molecule differs entirely from that known as mechanical elasticity. In perfectly soft iron we have feeble *mechanical* elasticity, whilst in tempered steel we have that elasticity at its maximum. The contrary takes place as regards *molecular* elasticity. In tempered steel the molecules are extremely rigid, and in soft iron its molecular elasticity is at its maximum. Its free motion differs entirely from that given it by torsion or stress. We may assume that a molecule is surrounded by continuous ether, more of the nature of a jelly than of that of a gas: in such a medium a molecule might freely vibrate through small arcs, but a rotation extending beyond its critical limit would involve a much greater expenditure of force.

The discovery of this comparatively free rotation of molecules, by means of which, as I have shown, we can (without in any degree disturbing the external mechanical elasticity of the mass) change the axes of their free motion in any direction desired, has led me into a series of researches which have only indirectly any relation with the theory of magnetism. I was extremely desirous, however, of finding an experimental evidence which in itself should demonstrate all portions of the theory, and the following experiment, I believe, answers this purpose.

Let us take a square soft iron rod, 5 millimetres in diameter by 30 or more centimetres in length, and force the molecules, by aid of blows from a wooden mallet, as previously described, to have their centres of free motion in one direction, the rod will (as already shown) have polarity at both ends, when held vertically; but if reversed, both ends become completely neutral.

If now we turn the rod to its first position, in which it shows strong polarity, and magnetise it whilst held vertically, by drawing the north pole of a sufficiently powerful permanent magnet from its upper to its lower extremity, we find that this rod, instead of having south polarity at its lower portion, as we should expect from the direction of the magnetisation, is completely neutral at both extremities, but if we reverse the rod, its fullest free powers of magnetisation now appear in the position where it was previously neutral. Thus, by magnetisation, we have completely rotated its free path of action, and find that we can rotate this path as desired in any direction by the application of a sufficient directing power.

If we take a rod as described, with its polarities evident when held vertically, and its neutrality also evident when its ends are reversed in the same magnetic field, we find that its polarity is equal at both ends, and that it is in every way symmetrical with a perfect magnet. If we *gradually* reverse the ends and take observations of its condition through each degree of arc passed over, we find an equal symmetrical diminution of evident external polarity until we arrive at neutrality, when it has no external trace of inherent polarity, but its inherent polarity at once becomes evident by a simple return to its former position. Thus the rod has passed through all the changes from polarity to neutrality, and from neutrality to polarity, and these changes have taken place with complete symmetry.

The limits of this paper do not allow me to speak of the numerous theoretical evidences as shown by the use of my induction balance. I believe, however, that I have cited already experimental evidences to show that what has been attributed to coercive force is really due to molecular freedom or rigidity; that in inherent molecular polarity we have a fact admitted by Coulomb, Poisson, Ampère, De la Rive, Weber, Du Moncel, Wiedermann, and Maxwell; and that we have also experimental evidence of molecular rotation and of the symmetrical character of polarity and neutrality.

The experiments which I have brought forward in this paper,

in addition to those mentioned in my paper read before the Royal Society, will, I hope, justify me in having advanced a theory of magnetism which I believe in every portion allows at least experimental evidences of its probable truth.

THE REDE LECTURE

THE following abstract report of Prof. Huxley's Rede Lecture given on Tuesday week in the Cambridge Senate House, to a crowded audience, has been revised, to the extent of removing any errors of importance, by the author. We understand that a full report of the lecture will shortly be published in a separate form.

Professor Huxley said he had undertaken to treat in the course of such time as custom and the patience of his audience might permit, on a very great subject, no less a subject than the origin of all those forms of animal life which at present existed. It had behoved him to restrict what he might lay before them to those considerations which were absolutely essential for his purpose, and he should endeavour to lay before them facts of such an order as appeared to him to be of most importance in reference to his argument. Although he might fail to put those facts before them as clearly as they presented themselves to his own mind, the reasonings which might be based upon them were of so simple an order that he should consider his task performed if he gave them a tolerably clear conception of what those facts were, for he did not think it was the business of a man of science to use the arts of rhetoric or endeavour to procure persuasion. His sole business was to place the facts before those whom he wished to teach, and to leave it to their reason to form such judgment upon those facts as they might think fit. In the present case he should point out to them what judgments such facts had forced upon his mind, but he must leave it entirely to their responsibility to say what judgment they might constrain them to give in their case. They might assume this position at starting, that, whatever in such a matter was true for one animal, was true for the infinite series of the whole animal world; and as he was extremely anxious to avoid everything speculative, everything that could not be directly led back to the matters of fact upon which it was based, he proposed to select one animal particularly, and to put before them facts and arguments by the help of which they might form some probable conclusion as to the origin of that object. He took it for granted that, if the evidence inclined towards a particular conclusion in the case of that animal, they might assume that it would incline in the same direction with regard to all. He had no doubt that a great many of his audience were familiar at any rate with the shell of the animal about which he was going to speak, namely, that of the pearly nautilus, from which, or parts of which, very beautiful ornaments were fabricated. At the present time the nautilus inhabited the warmer parts of the Indian and Pacific Oceans, living at considerable depths and preying upon the hard shelled crustaceans and mollusks that crept along the bottom, and which it found in its way. For that end it was provided with a very curious beak, shaped like that of a parrot, but with each portion covered with a hard calcareous deposit, and which enabled it to be an efficient instrument for crushing its prey. If he were to touch upon the morphological problem which here presented itself, he could occupy far more time than they had at their disposal with the consideration of a multitude of interesting peculiarities which the nautilus presented, for it was one of those forms which at present stood almost isolated and alone in the animal world, separated by a wide gulf from its nearest allies, those animals which they knew as squids and cuttle-fishes. It held the middle place between sea-snails and the group of the cuttle-fishes. It would be, however, entirely out of place at present, and a purposeless waste of time if he were to touch upon any peculiarities except those which would be needed during his further argument. The only points to which he would direct their attention for that purpose were the facts which related to the structure of the shell. There was a diagram beside him showing a part of the nautilus shell in section, but he thought it possible that he could make the matter clearer by roughly sketching on the board the main points as he went on.—Prof. Huxley here described, with the aid of diagrams, preserved specimens, and models, the complicated structure of the shells of the pearly nautilus, or *Nautilus pompilius*. The animal itself was contained in the spacious chamber in the outer part of the shell, which was divided from the rest of the shell by a partition. The rest of the shell resembled a long cone closely coiled up, and divided by partitions at regular intervals into other chambers, which succeeded one another, and in the full-grown animal were full of air. From the hinder part of the animal's body a long tube, the siphuncle, was carried backwards through the whole of the shell, and as it completely filled up the openings in the partitions through which it passed there was no communication between one chamber and another. The first point to be considered was as to what was the origin of the particular nautilus in the bottle before him. Happily there was no dispute upon that point. The female nautilus contained eggs exactly as the hen did. These eggs were small masses of protoplasmic matter, each containing a nucleus in its centre, which was all that was essential. They knew that that pearly nautilus with all its complicated organism, and fitted with the complicated shell he had described, did, in some way or other, proceed from that relatively structureless body which they called the egg or the ovum. As fate would have it, up to the present they had known nothing from direct observation of the process by which that particular animal was produced from this microscopic particle. But they had so large a knowledge of the process in other animals of every description that there was no doubt whatever as to the nature of the process, which he would try to describe to them as briefly as possible, by reference to the process which took place in the case of the domestic hen. Neither by the highest powers of the microscope, nor by other means of investigation which they had at present, could they trace anything in the slightest degree resembling either the chick, which under certain circumstances proceeded from that egg, or the tissues of the chick. There was, however, one spot on the yolk of the egg, a little careful observation of which would show a clear space, which might be a fifth of an inch in diameter. It was very well known by the name of the cicatricula, or little scar. He would suppose that twenty-one eggs were placed together under the hen. If they took one egg day by day and examined it they would know what took place as if they had watched continuously, for what happened in any one egg happened also in the others. That was a process—the wonder of which he must confess never staled in his mind—by which the chick was gradually fashioned out of that transparent rudiment. They saw it make its appearance in the first place on the surface of the yolk, and to the naked eye it looked like a white streak. That white streak gradually assumed the appearance of a sort of elongated body, and that body shaped itself so that it could be seen that it was going to be an animal of some kind, it having a large head, and the rudiments of eyes and vertebræ. On the fifth day they could clearly see what they were going to have. Gradually, step by step, and moment by moment, new differences made their appearance from the original foundation, and until many days before hatching there was an unmistakable bird, and at the twenty-first day there emerged from the shell an animal endowed with all a bird's capacities and structures. That process was the process of development. If they inquired into the nature of the cicatricula, they would find that that was merely a double layer of minute nucleated cells. They would find that that resulted from the splitting up of a protoplasmic mass that had been there before. They could trace the process back into the body of the hen until they came down to a simple nucleated cell, so that it was a matter capable of demonstration that in that nucleated cell which formed a part of the egg organ of the hen—in that particle of, for morphological purposes, structureless jelly, were the same characteristics which were possessed by the very lowest forms of animal life which were known. They knew that in that particle resided a potentiality, capable of developing itself through the stages he had roughly indicated, until it became not only a machine of the highest order from a physiological point of view, but a very remarkable work of art. That particle of protoplasmic matter did that in virtue of the powers inherent in its material nature. That was the point he wished to put before them as clearly and definitely as he could, because it would be fundamental in all further discussion. For it was to the process he had briefly described that the great discoverers of the last two centuries applied the name of "evolution." Singularly enough the persons who first used that name did not use it in that sense in which it was universally used now, because they were under a mistake as to the exact nature of the process. But the whole conception of evolution was now based upon ascertained facts, showing the process of development of the most complicated animal out of a relatively structureless particle, which had no higher organisation than that of the